NATIONAL UNIVERSITY OF SINGAPORE

EE5703 – INDUSTRIAL DRIVES

(Semester 1 : AY2018/2019)

Time Allowed : 2 Hours

INSTRUCTIONS TO STUDENTS

1. Please write only your Student Number. Do not write your name.
2. This assessment paper contains **SIX** questions and comprises **FOUR** printed pages.
3. Students are required to answer **ALL** questions.
4. Students should write the answers for each question on a new page.
5. This is a CLOSED BOOK assessment.
6. Programmable calculators are permitted.
7. Total Marks is 60.

Q.1 (a) A 3-phase permanent magnet synchronous motor (PMSM) is supplied from a balanced 3-phase source of 415V/50Hz. The motor is controlled using space vector control method. The motor has a torque constant, $K_T = 0.5$ *Nm/A*. When the motor is operating in steady-state with the load torque of 10 *Nm*.

i. determine the stator currents i_{sd}, and i_{sq} in the d-q reference frame, where d-axis is aligned with the rotor magnetic field.

(2 marks)

ii. determine the stator phase currents i_a, i_b and i_c when the rotor magnetic field is at 60^0 away from the magnetic axis of a-phase winding?

(3 marks)

Q.1 (b) Derive the torque equation in terms of the d-q components of stator current, starting with the stator winding voltage equation in space vector in fixed reference frame:

$$\vec{v}_s = r_s\vec{i}_s + \frac{d\vec{\lambda}_s}{dt}$$

(5 marks)

Q.1 (c) Briefly describe torque control method for PMSM in d-q reference frame. List one suitable application for PMSM.

(5 marks)

Q.2 (a) A 4-pole induction motor is supplied from balanced 3-phase source of 415V/50Hz. The equivalent circuit parameters given as in the Figure Q.2(a) as:
$R_s = 0.5\Omega, X_{ls} = 0.6\Omega, R'_r = 0.45\Omega, X'_{lr} = 0.2\Omega, X_m = 28\Omega.$

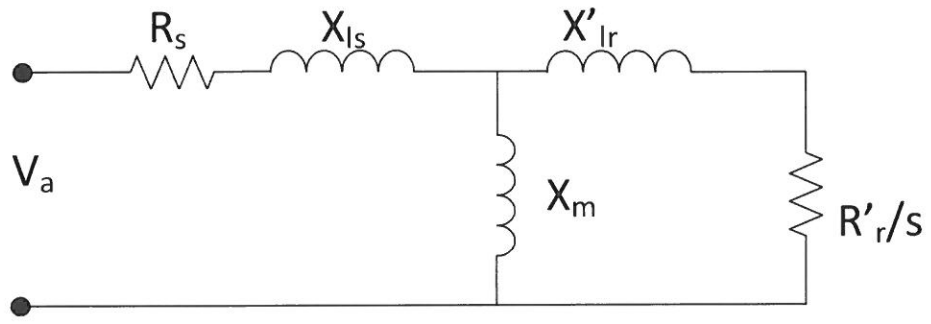

Figure Q.2(a) Per phase equivalent circuit of induction motor

When the motor is operating in steady-state and slip $s = 0.04$, determine

- stator current,
- power factor, and
- efficiency of the motor.

(6 marks)

Q.2 (b) Draw the block diagram for the V/f controller for induction motor clearly describing the role of each block.

(6 marks)

Q.2 (c) What should be stator voltage applied to the induction motor under V/f control, when the motor operates at half the rated speed and under half the rated load.

(3 marks)

Q.3 (a) Mention two key benefits of electrical Equipment Health Monitoring (eEHM). Also mention two key challenges in realizing eEHM for an Electric Drive Systems.

(2 marks)

Q.3 (b) Write a short article on any real life electric drive application known to you. Draw the electrical schematic of this drive? Please include comments on the following.

- the type of electric motor and power converter used in the electric drive,
- characteristics of the selected electric drive including merits and demerits.

(4 marks)

Q.4 (a) For a separately excited DC motor shown in the Figure Q.4(a), develop $\dot{X} = AX + BU$ and provide matrices A and B given $X = [i_a \quad w_m]^T$, $U = [V_a \quad T_L]^T$. Briefly explain the speed control methodology for both above and below the base speed for such a DC motor.

(4 marks)

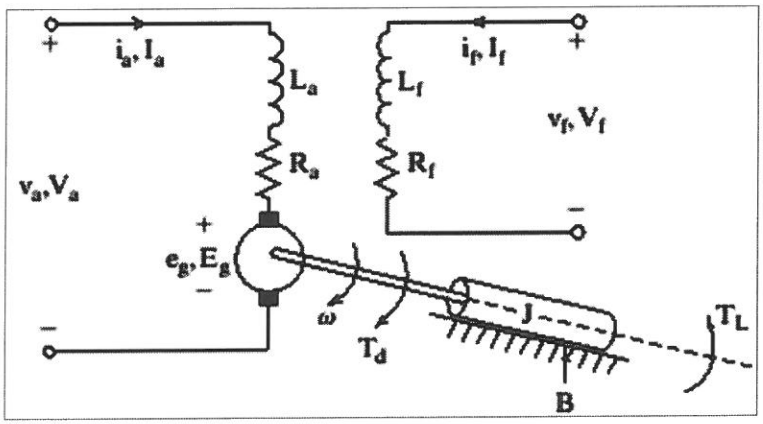

Figure Q.4(a) Separately excited DC motor

Q.4 (b) A 220V DC series motor runs at 700 rpm when operating at its full-load current of 20A. The motor resistance is 0.5Ω and the magnetic circuit may be assumed to be unsaturated. Calculate the motor speed when

- the load torque is increased by 44% and
- the motor current is 10A.

(2 marks)

Q.4 (c) A separately excited DC motor is controlled using a DC-DC buck converter with the 600V DC supply used at the armature circuit. The armature resistance is 0.5Ω. The constant for the back EMF is 1.527 V/A rad/s. The armature current is set to 250A and is assumed to be ripple-free and continuous. The field current is set to 4A. If the operating duty cycle of the DC-DC buck converter is 60%, calculate the following:

- input power from the DC supply,
- motor speed, and
- developed torque.

(3 marks)

Q.5 (a) Please explain the differences between the working principle and construction of Switched Reluctance Motor (SRM) and Permanent Magnet DC (PMDC) motor.

(4 marks)

Q.5 (b) Why is it beneficial to operate SRM in deep saturation mode?

(2 marks)

Q.5 (c) Why do we need power electronic converter to operate a switched reluctance motor (SRM)? How does the failure in a power switch impact SRM's operation?

(2 marks)

Q.6 (a) Please explain the difference between the working principle of Permanent Magnet Synchronous Motor (PMSM) and Brushless DC (BLDC) motor. Draw typical waveforms for back EMF and stator current for the PMSM and BLDC.

(4 marks)

Q.6 (b) Mention two disadvantages associated with the slip rings of a synchronous motor. Draw the circuit diagram for a brushless exciter used in a synchronous motor.

(3 marks)

END OF PAPER